LiDAR Quality Assurance (QA) Report
Laurens County, South Carolina
February 20, 2009

Submitted to:
USGS
Prepared by:

Dewberry
Fairfax, VA

EXECUTIVE SUMMARY

Reference: USGS Contract 07CRCN0004, Task Order 07004C0009, South Carolina 16 County LiDAR, dated January 17, 2008.

This report documents Dewberry's actions to quality assure the LiDAR deliverables of Laurens County, SC, produced by Dewberry's subcontractor, Fugro EarthData, under the referenced USGS task order. The LiDAR data was acquired in January of 2008 and delivered as LiDAR LAS point cloud data in five ASPRS LAS classes (class 1 = non-ground; class 2 = ground; class 8 = intelligently-thinned model key points; class 9 = water; and class 12 = overlap points not used in other classes). The LiDAR data was determined to be of excellent quality.

Completeness: Dewberry verified the completeness of the classified LiDAR points, intensity images, and an ESRI geodatabase containing a terrain (triangulated irregular network) and ground masspoints. Hydrographic breaklines were delivered separately by watershed. Dewberry verified that the high density mass point data has an average point spacing less than 1.4m, that 900 tiles (each 5000 ft x 5000 ft) were delivered covering all of Laurens County, that all data was delivered in the correct file format and projected to the South Carolina State Plane Coordinate System in International feet, NAD83 HARN, with elevations in meters, NAVD88; and that the FGDC-complaint metadata satisfies project requirements.

Quantitative: Using checkpoints surveyed by the South Carolina Geodetic Survey, Dewberry tested the RMSEz, Fundamental Vertical Accuracy (FVA) in open terrain, Consolidated Vertical Accuracy (CVA) in all land cover categories, and Supplemental Vertical Accuracy (SVA) in each of three major land cover categories per FEMA requirements, and the accuracy easily surpassed the specified accuracy required, as summarized below, when tested per FEMA, NSSDA, NDEP and ASPRS guidelines.

Criterion	Checkpoints Required	Checkpoints Used	Accuracy Specification	Results Achieved
RMSEz	60	130	18.5 cm	11.4 cm
FVA	20	44	36.3 cm	25.0 cm
CVA	60	130	36.3 cm	19.4 cm
SVA-bare earth	20	44	36.3 cm	23.3 cm
SVA-vegetated	20	65	36.3 cm	18.2 cm
SVA-urban	20	21	36.3 cm	18.9 cm

Qualitative: Dewberry visually inspected 100% of the data; no remote-sensing data voids were found and the data is free of major systematic errors. The cleanliness of the bare earth model meets expectations; minor errors were found in less than 2% of the data, including acquisition drop-off. All of the deliverables extend to the county boundaries where adjoining counties are not delivered; and where adjoining counties are delivered there is no clipping of the tiles.

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QA REPORT

1 Introduction

The following definitions are provided to distinguish between steps taken by Dewberry, as prime contractor, to provide Quality Assurance (QA) of the LiDAR data produced by Fugro EarthData, and steps taken by Fugro EarthData, as data producer, to perform Quality Control (QC) of the data that it provides to Dewberry. Collectively, this QA/QC process ensures that the LiDAR data delivered to USGS and its client (South Carolina Department of Natural Resources) are accurate, usable, and in conformance with the deliverables specified in the Scope of Work. These definitions are taken from the DEM Quality Assessment chapter of the 2nd edition of "Digital Elevation Model Technologies and Applications: The DEM Users Manual," published by the American Society for Photogrammetry and Remote Sensing (ASPRS), 2007:

> **Quality Assurance (QA)** — Steps taken: (1) to ensure the end client receives the quality products it pays for, consistent with the Scope of Work, and/or (2) to ensure an organization's Quality Program works effectively. Quality Programs include quality control procedures for specific products as well as overall Quality Plans that typically mandate an organization's communication procedures, document and data control procedures, quality audit procedures, and training programs necessary for delivery of quality products and services.
>
> **Quality Control (QC)** — Steps taken by data producers to ensure delivery of products that satisfy standards, guidelines and specifications identified in the Scope of Work. These steps typically include production flow charts with built-in procedures to ensure quality at each step of the work flow, in-process quality reviews, and/or final quality inspections prior to delivery of products to a client.

Dewberry's role is to provide overall project management as well as quality management that include QA of the data including a completeness validation of the LiDAR masspoints, vertical accuracy assessment and reporting, and a qualitative review of the derived bare earth surface. In addition, Dewberry provides an extensive review of other derived products such as 3D streamlines, TIN-terrain, and LiDAR intensity images.

First, the completeness verification is conducted at a project scale (files are considered as the entities) for all products. It consists of a file inventory and a validation of conformity to format, projection, and georeference specifications. At this point Dewberry also ensures that the data adequately covers the project area for all products. The LiDAR data review begins with the computation of general statistics over all fields per file, followed by an analysis of the results to identify anomalies, especially in the elevation fields and LAS class fields.

The quantitative analysis addresses the quality of the data based on absolute accuracy of a limited collection of discrete checkpoint survey measurements. Although only a small amount of points are actually tested through the quantitative assessment, there is an increased level of confidence with LiDAR data due to the relative accuracy. This relative accuracy in turn is based on how well one LiDAR point "fits" in comparison to surrounding LiDAR measurements as acquisition conditions remain similar from one point to the next.

To fully address the LiDAR data for overall accuracy and quality, a manual qualitative review for anomalies and artifacts is conducted on each tile. This includes creating pseudo-image products such as 3-dimensional models. The QA analyst uses multiple images and using overlays to find potential errors in the data as well as areas where the data meets and exceeds expectations.

Three fundamental questions are addressed during Dewberry's QA process:

- Was the data complete?
- Did the LiDAR system perform to specifications?
- Did the ground classification process yield desirable results for the intended bare-earth terrain product?

Under the referenced task order, LiDAR data was acquired for 16 counties in South Carolina (Figure 1). This report focuses on the deliverables covering Laurens County that are directly derived from the LiDAR. The hydrolines, derived from the LiDAR, are being delivered per watershed and thus will be discussed in a subsequent report. All quality assurance processes and results are given in the following sections.

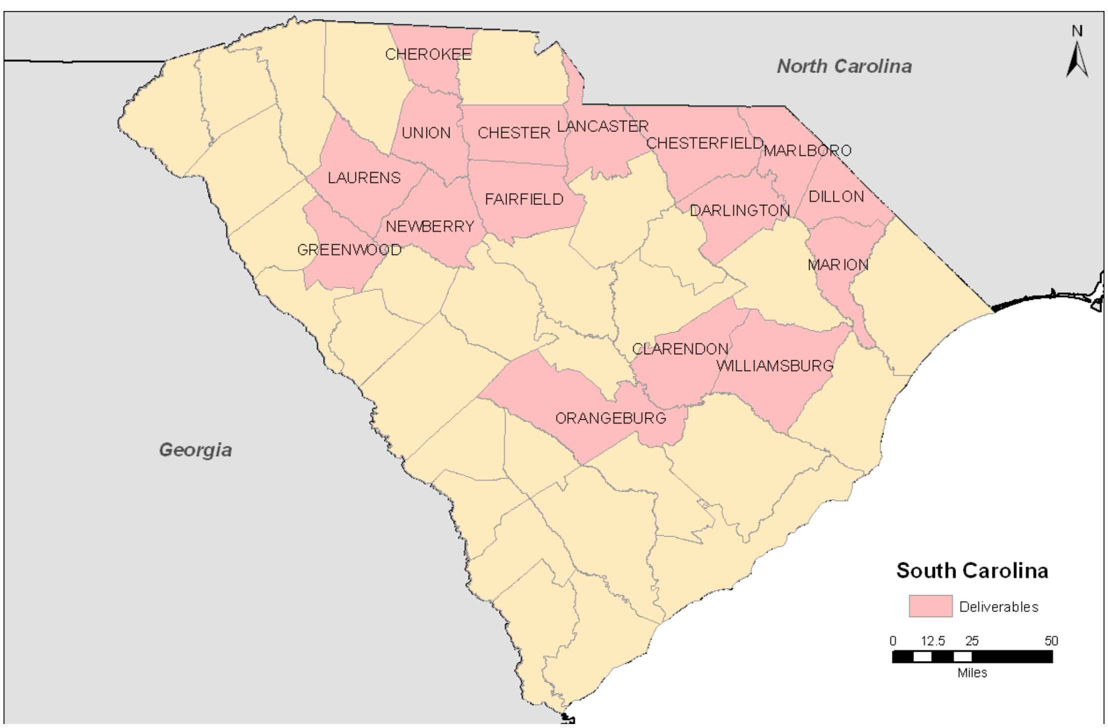

***Figure 1** – Project area; the 16 deliverable counties for the South Carolina project are shown in pink.*

2 Completeness of deliverables

Dewberry reviews the inventory of the data delivered by validating the format, projection, and georeferencing. County based deliverables are listed in **Table 1**.

Table 1 - County deliverables.

Dataset	Format	Spatial
LiDAR	LAS	Tiled
Intensity images	GeoTiff	Tiled
Terrain (bare earth)	ESRI feature class Terrain	1feature class
Ground masspoints	ESRI feature class multipoints	1feature class
Boundary	ESRI geodatabase feature class - polygons	3 feature classes (county/tile/LiDAR)

Clipping of the data along the county boundary was performed according to the following rules (Figure 2):

- a partial tile is delivered at the boundary with a county that is not part of the project,
- a full tile is delivered at the boundary with a county that is part of the project

LAS files and intensity images were delivered in tiles that adhere to these rules and to the State of South Carolina's 5000 ft x 5000 ft tile schema (see Figure 3). The LAS, the ground masspoint feature class, terrain, and intensity images extend outside the project boundary with a 50 ft buffer (Figure 4 and Figure 5) as expected.

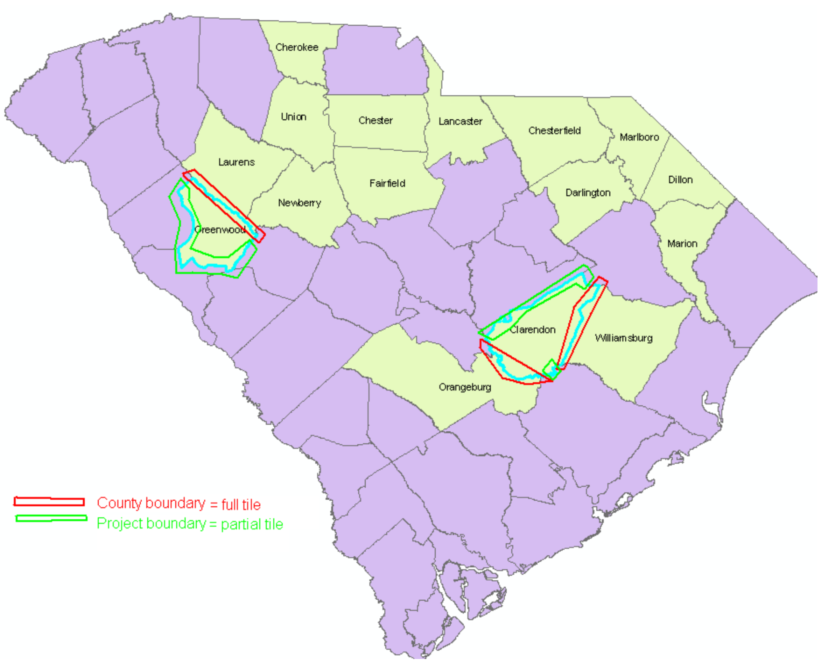

Figure 2 *– Convention used for the tile coverage: at the boundary of a county that is not part of the project, a partial tile is delivered; at the boundary of a county that is part of the project, a full tile is delivered.*

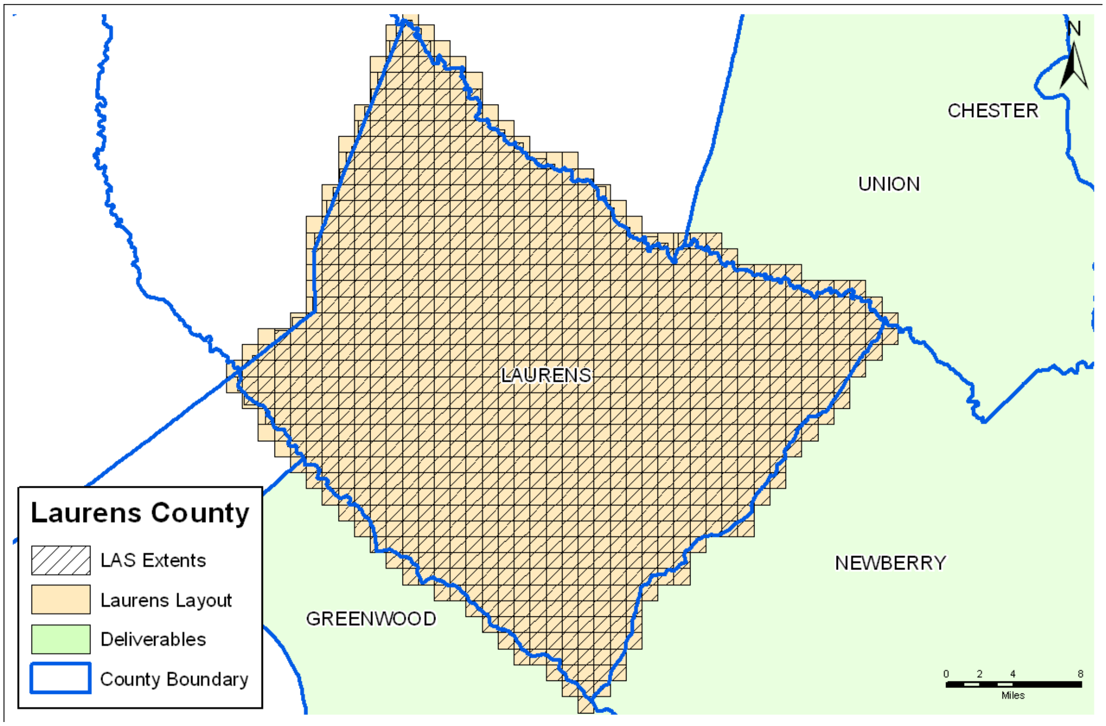

Figure 3 *– The LiDAR coverage of Laurens County. Neighboring deliverable counties are shown in green.*

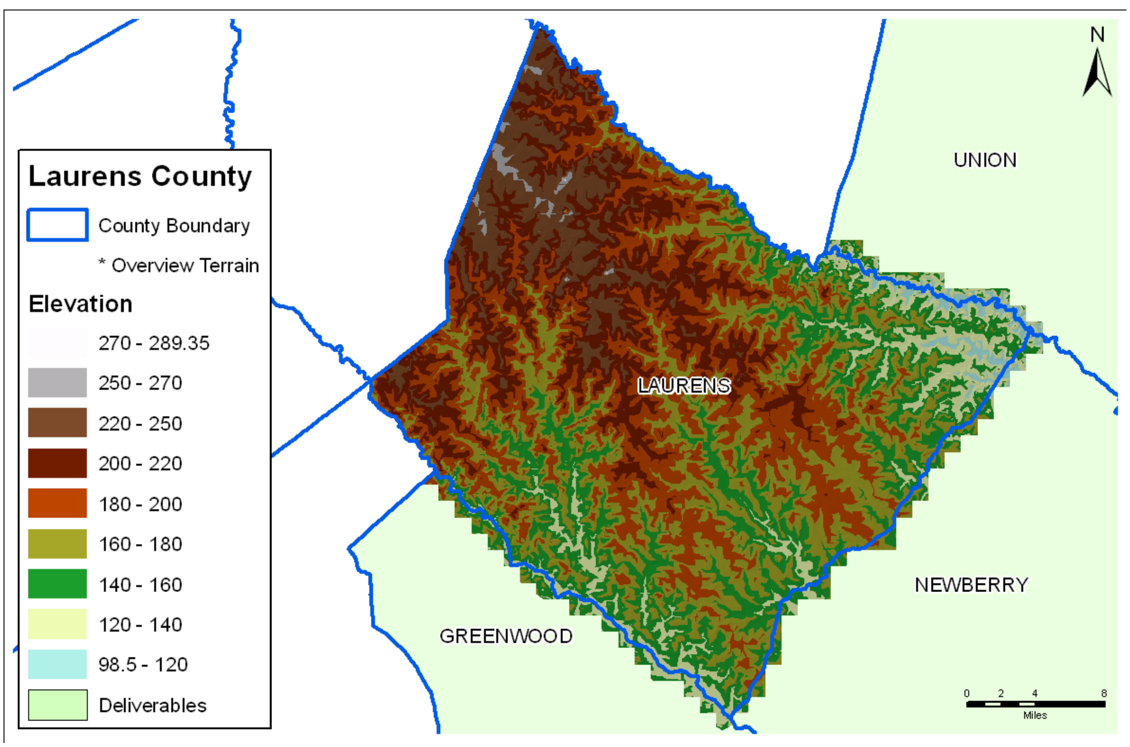

Figure 4 *– The terrain for Laurens has a 50 ft buffer outside of the project boundary.*

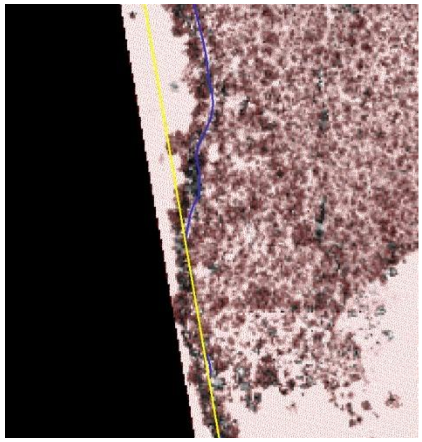

Figure 5 *- Ground masspoints (red) and intensity images extend 50 feet outside the project boundary in yellow. The LAS and terrain do the same. Hydrolines are clipped at the project boundary and the watershed boundary.*

3 QA of intensity images

900 intensity images in GeoTiff format were delivered for Laurens County. An automated script was used to validate that intensity values are integers ranging between 0 and 255, that the cell size is 4 ft, and that the column and row count is 1250. 1250 multiplied by 4 (the pixel size in feet) equals 5000 feet which is the required size of the tiles: 5000 ft x 5000 ft. Another automated script was used to validate the header information on all of the GeoTiffs. There were no issues with these checks. An example of the header is shown in Table 2.

Table 2 – Intensity header.

File Name: 6020-02.tif	Geotiff_Information:
File Information:	Version: 1
Standard : : TIFF File	Key_Revision: 1.0
Format : : Byte integers (8 bits)	Tagged_Information:
Pixels per Line : 1250	ModelTiepointTag (2,3):
Number of Lines : 1250	0 0 0
Samples per pixel : 1	1625000 1010000 0
File bits per sample : 8	ModelPixelScaleTag (1,3):
Actual bits per sample : 8	4 4 0
Untiled file	End_Of_Tags.
Number of overviews : 0	Keyed_Information:
Scanning device resolution : 72 : lines/inch	GTModelTypeGeoKey (Short,1): ModelTypeProjected
Orientation : 4 : Row major order, origin at top left	GTRasterTypeGeoKey (Short,1): RasterPixelIsArea
NO scan line headers : non-scannable file	ProjectedCSTypeGeoKey (Short,1): Unknown-3361
Packet size (16-bit words) : 0	ProjLinearUnitsGeoKey (Short,1): Linear_Foot
Free vlt space (16-bit words) : 2000000000	End_Of_Keys.
Free packet space (16-bit words) : 2000000000	End_Of_Geotiff.
Raster to UOR matrix:	PCS = 3361 (name unknown)
Unspecified or All Zero Matrix	Projection Linear Units: 9002/foot (0.304800m)
Raster to World Matrix:	Corner Coordinates:
Units: Feet	Upper Left (1625000.000,1010000.000)
amx[0]= 4, amx[1]= 0, amx[2]= 1625000	Lower Left (1625000.000,1005000.000)
amx[3]= 0, amx[4]= -4, amx[5]= 1010000	Upper Right (1630000.000,1010000.000)
1625000 , 1010000	Lower Right (1630000.000,1005000.000)
1630000 , 1010000	Center (1627500.000,1007500.000)
1630000 , 1005000	
1625000 , 1005000	

Dewberry also visually checked the tile-matching in ArcMap. Overall, the intensity is consistent between adjacent tiles. Tiles over the boundary between two delivered counties are delivered in full for each county. Tiles over the outside project boundary are partial; the section outside the buffered project area is filled with black pixels (value 0).

One intensity issue that was found a few times in the Laurens LiDAR data was tonal differences within a tile. These changes in intensity values seem to correspond with the flight line boundaries as shown in Figure 6. Dewberry does not consider this a significant problem but rather a point of interest.

Figure 6 *- 6040-01 Tonal changes with a tile.*

4 Metadata

Dewberry verified the metadata and all of the xml files were FGDC compliant. Metadata is delivered for the project, terrain, intensity images, and the LAS.

5 LiDAR QA

5.1 Completeness

5.1.1 LAS inventory

Dewberry received 646 LiDAR files covering the Laurens County area. They are in the correct format and projection:

- LAS version: 1.1
- Point data format: 1
- Projection set in the header:
    - NAD_1983_HARN_StatePlane_South_Carolina_FIPS_3900_Feet_Intl;

- Horizontal unit: linear feet;
- NAVD88 - Geoid03;
- Vertical unit: meters

The point spacing matches the requirement of an average point spacing of 1.4 meters.

Each record includes the following fields:

- XYZ coordinates
- Flight line
- Intensity
- Return number, number of return, scan direction, edge of a flight line and scan angle
- Classification:
  - class 1 for non-ground,
  - class 2 for ground (must be combined with class 8 to be complete),
  - class 8 for (intelligently-thinned) model key points,
  - class 9 for water,
  - class 12 for overlap
- GPS time (this is expressed in second of the week; note that the date of collection will be given in the metadata file because the date contained in the LAS header is the file creation date according to LAS standard)

5.1.2 Statistical analysis of LAS tile content

To verify the content of the data and to validate the data integrity, a statistical analysis was performed on all the data. This process allows Dewberry to statistically review 100% of the data to identify any gross outliers. This statistical analysis consists of:

1. Extracting the header information
2. Reading the actual records and computing the number of points, minimum, maximum and mean elevation for each class. Minimum and maximum for other relevant variables are also evaluated.

Each tile was queried to extract the number of LiDAR points. With a nominal point spacing of less than 1.4m, the number of points per tile should be around 3.9 million. The mean in Laurens County is around 5.2 million which proves that the average density is more than what is required. All tiles are within the anticipated size range except for where fewer points are expected (near the external project boundary where tiles are clipped or over large rivers and lakes) as illustrated in Figure 7.

To first identify incorrect elevations, the z-minimum and z-maximum values for the ground class were reviewed. With maximum values between 143.0m and 289.0m, no noticeable anomalies were identified because this is consistent with the expected range of elevation in the county. Figure 8 (right) shows the spatial distribution of these elevations, following the anticipated terrain topography. Lower elevations are found near hydrographic features; see Figure 8 (left) for the Z min elevations.

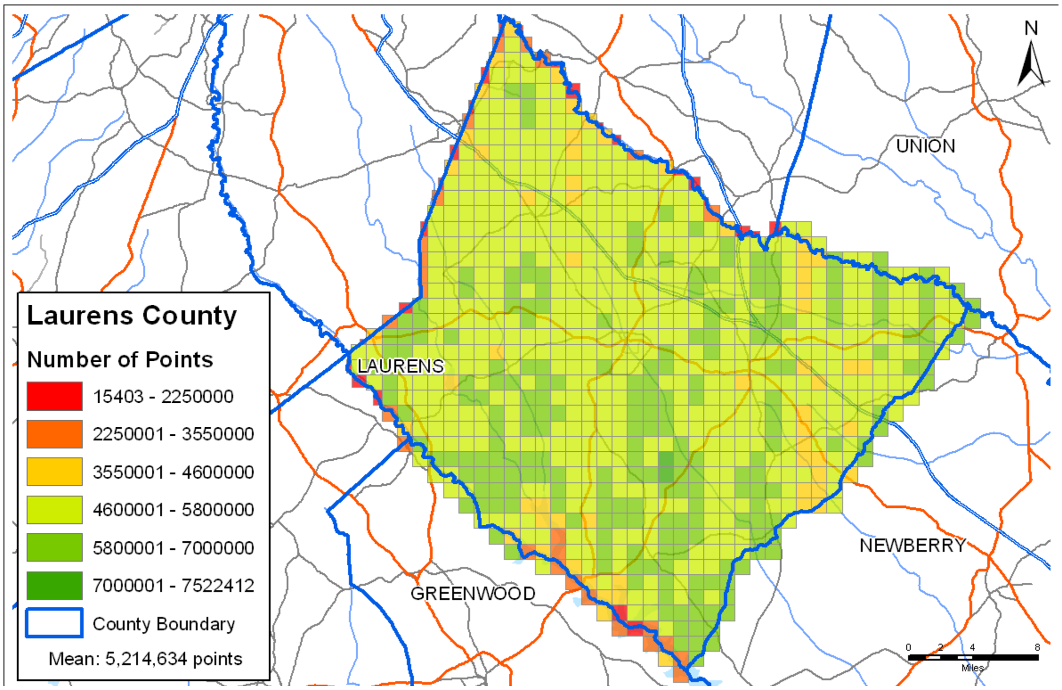

Figure 7 *– Number of points per tile. The red tiles at the border are expected to have fewer points.*

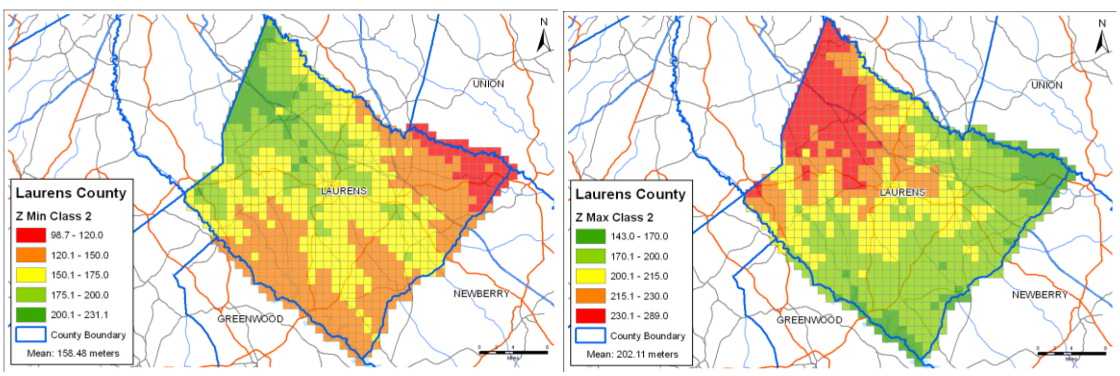

Figure 8 *– Z min and Z max elevation by tile for ground points (class 2).*

5.2 LiDAR Quantitative Assessment

5.2.1 Checkpoint inventory

Typically for this type of data collection, a ground truth survey is conducted following the *FEMA Guidelines and Specifications for Flood Hazard Mapping Partners Appendix A: Guidance for Aerial mapping and Surveying* which is based on the NSSDA. This methodology collects a minimum of 20 points for each of the predominant land cover types (i.e. bare-earth, weeds and crop, forest, urban etc.) for a minimum of three land cover classes. By verifying the data in these different classes, the data accuracy is tested, but it also tests whether the classification of the LiDAR was performed correctly at those test point locations. In this project the predominant land covers selected are bare-earth, mixed vegetation, and urban.

The field survey was conducted and prepared by the South Carolina Geodetic Survey in April 2008. The guidelines were to collect 60 checkpoints in 3 different land covers: 20 points in Urban Areas, 20 points in Open Terrain, and 20 points divided equally in Medium Vegetation and Forested Areas.

In reality 139 points were collected, as presented in Table 3, with 68 vegetation points instead of 20, including an additional class (bush). All the checkpoints used for the vertical assessment of the LiDAR data are available in Appendix A. Figure 9 shows the distribution of the checkpoints throughout the area. The points are grouped together in clusters. In some cases the checkpoints within a cluster are less than 100 ft apart which is not ideal but still acceptable.

Table 3 - Number of points required and acquired.

Class	Guidelines	Acquired
o - Open Terrain	20	49
b - Bush	0	20
h - High Grass	10	28
w - Woods	10	20
u - Urban	20	22
Total	**60**	**139**

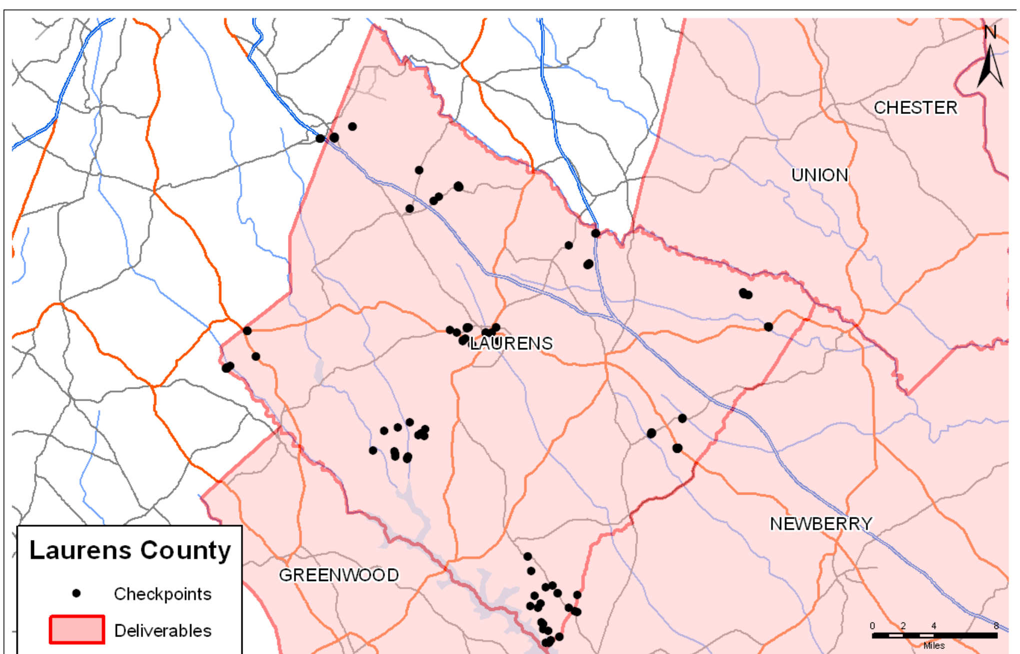

***Figure 9** – Survey checkpoints from South Carolina Geodetic Survey.*

5.2.2 Vertical Accuracy Assessment Methodologies

The first method of testing vertical accuracy used the FEMA specifications which follows the National Standard for Spatial Data Accuracy (NSSDA) procedures. The accuracy is reported at the 95% confidence level using the Root Mean Square Error (RMSE) which is valid when errors follow a normal distribution. By this method, vertical accuracy at the

95% confidence level equals RMSEz x 1.9600. This methodology measures the square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points. The vertical accuracy assessment compares the measured survey checkpoint elevations with those of the TIN as generated from the bare-earth LiDAR. The X/Y locations of the survey checkpoints are overlaid on the TIN and the interpolated Z values are recorded. These interpolated Z values are then compared with the survey checkpoint Z values and this difference represents the amount of error between the measurements.

The second method of testing vertical accuracy, endorsed by the National Digital Elevation Program (NDEP) and American Society for Photogrammetry and Remote Sensing (ASPRS) uses the same (RMSE) method in open terrain only; an alternative method uses the 95th percentile to report vertical accuracy in each of the other land cover categories (defined as Supplemental Vertical Accuracy – SVA) and all land cover categories combined (defined as Consolidated Vertical Accuracy – CVA). The 95th percentile method is used when vertical errors may not follow a normal error distribution, as in vegetated terrain.

The Fundamental Vertical Accuracy (FVA) is the same for both methods; both methods utilize RMSE x 1.9600 in open terrain where there is no reason for LiDAR errors to depart from a normal error distribution.

The following tables and graphs outline the vertical accuracy and the statistics of the associated errors as computed by the different methods.

Table 4 shows the complete results of the Laurens County data set run through the FEMA/NSSDA process; vertical accuracy at the 95% confidence level equals the RMSE x 1.9600. By this method, the consolidated vertical accuracy equals the RMSE (0.114 m) x 1.9600, or 0.223 m (22.3 cm).

Table 4 - Final statistics for Laurens County using FEMA/NSSDA processes.

100 % of Totals	RMSE (m) Spec=0.185m	Mean (m)	Median (m)	Skew	Std Dev (m)	# of Points	Min (m)	Max (m)
Consolidated	0.114	-0.059	-0.072	0.447	0.098	130	-0.319	0.244
Open Terrain	0.128	-0.090	-0.097	0.027	0.092	44	-0.319	0.107
Vegetated	0.102	-0.034	-0.050	0.761	0.097	65	-0.192	0.244
Urban	0.119	-0.074	-0.072	0.359	0.096	21	-0.252	0.132

Table 5 shows the complete results of the Laurens data set run through the NDEP/ASPRS process; the CVA value is 0.194 m (19.4 cm). The similar results between the two methods 22.3 cm and 19.4 cm demonstrate that the errors approximate a normal error distribution. All of the calculated statistics for Laurens County fall well below the specifications.

Table 5 - Final statistics for Laurens County using NDEP/ASPRS processes.

Land Cover Category	# of Points	FVA — Fundamental Vertical Accuracy (RMSEz x 1.9600) Spec=36.3 cm	CVA — Consolidated Vertical Accuracy (95th Percentile) Spec=36.3 cm	SVA — Supplemental Vertical Accuracy (95th Percentile) Target=36.3 cm
Consolidated	130		19.4	
Bare Earth	44	25.0		23.3
Vegetated	65			18.2
Urban	21			18.9

Figure 10 illustrates the distribution of the elevation differences between the LiDAR data and the surveyed checkpoints. The majority of delta Z values are below zero which indicates a slightly negative error distribution.

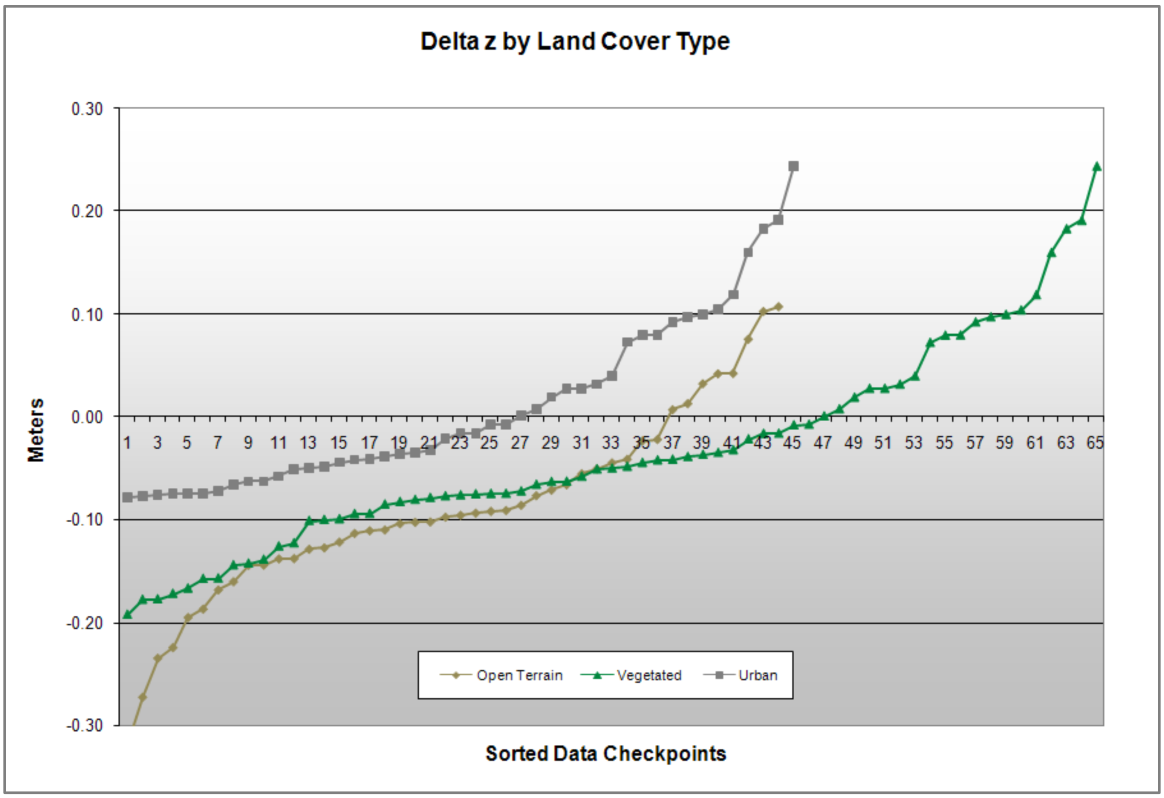

Figure 10 - *Checkpoints shown per land cover type and sorted by errors (DeltaZ).*

Given the good results and the high number of checkpoints used, Dewberry is confident that the data meets the accuracy requirements despite the less than ideal spatial dispersion of the checkpoints.

Compared with the 36.3 cm specification for vertical accuracy at the 95% confidence level, equivalent to 2-foot contours, the dataset passes by all methods of accuracy assessment:

- Tested 25.0 cm Fundamental Vertical Accuracy at 95% confidence level in open terrain using RMSEz x 1.9600 (FEMA/NSSDA and NDEP/ASPRS methodologies).
- Tested 22.3 cm Consolidated Vertical Accuracy at 95% confidence level in all land cover categories combined using RMSEz x 1.9600 (FEMA/NSSDA methodology).
- Tested 19.4 cm Consolidated Vertical Accuracy at 95^{th} percentile in all land cover categories combined (NDEP/ASPRS methodology).

5.3 LiDAR Qualitative Assessment

5.3.1 Protocol

The goal of Dewberry's qualitative review is to assess the continuity and the level of cleanliness of the bare earth product. Each LiDAR tile is expected to meet the following acceptance criteria:

- The point density is homogeneous and sufficient to meet the user's needs;
- The ground points have been correctly classified (no manmade structures and vegetation remains, no gap except over water bodies);
- The ground surface model exhibits a correct definition (no aggressive classification, no over-smoothing, no inconsistency in the post-processing);
- No obvious anomalies due to sensor malfunction or systematic processing artifact is present (data holidays, spikes, divots, ridges between tiles, cornrows…);
- 90% or more of the artifacts have been removed, 95% of the outliers, 95% of the vegetation, and 98% of the buildings.

Dewberry analysts, experienced in evaluating LIDAR data, performed a visual inspection of the bare-earth digital elevation model (bare-earth DEM). LiDAR masspoints were first gridded with a grid distance of 2x the full point cloud resolution. Then, a triangulated irregular network (TIN) was built based on this gridded DEM and displayed as a 3D surface. A shaded relief effect was applied which enhances 3D rendering. The software used for visualization allows the user to navigate, zoom and rotate models and to display elevation information with an adaptive color coding in order to better identify anomalies.

One of the variables established when creating the models is the threshold for missing data. For each individual triangle, the point density information is stored; if it meets the threshold, the corresponding surface will be displayed in green, if not it will be displayed in red (see Figure 11). It should also be noted that if this density model is created with the ground points only, it is expected to have void areas where buildings exist or in water; vegetation can also reduce the number of points hitting the ground, resulting in more distanced points.

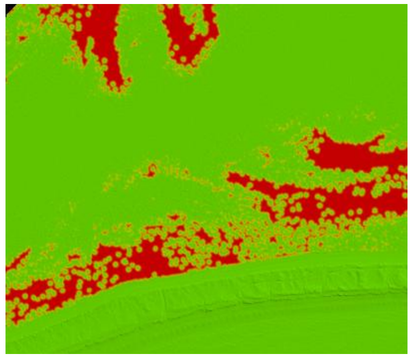

Figure 11 *– Ground model with density information (red means sparse data).*

The first step of Dewberry's qualitative workflow was to verify the point distribution by systematically loading a percentage of the tiles as masspoints colored by flight line (Figure 12) or by class (Figure 13). This particular type of display helps us visualize and better understand the scan pattern, the flight line orientation, flight coverage, and gives an additional confirmation that all classes are present and seem to logically represent the terrain.

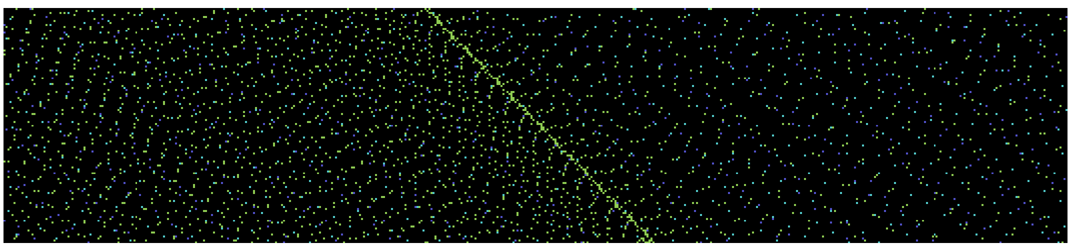

Figure 12 *– Detail of LiDAR points colored by flight line. Note the variations in the scan pattern.*

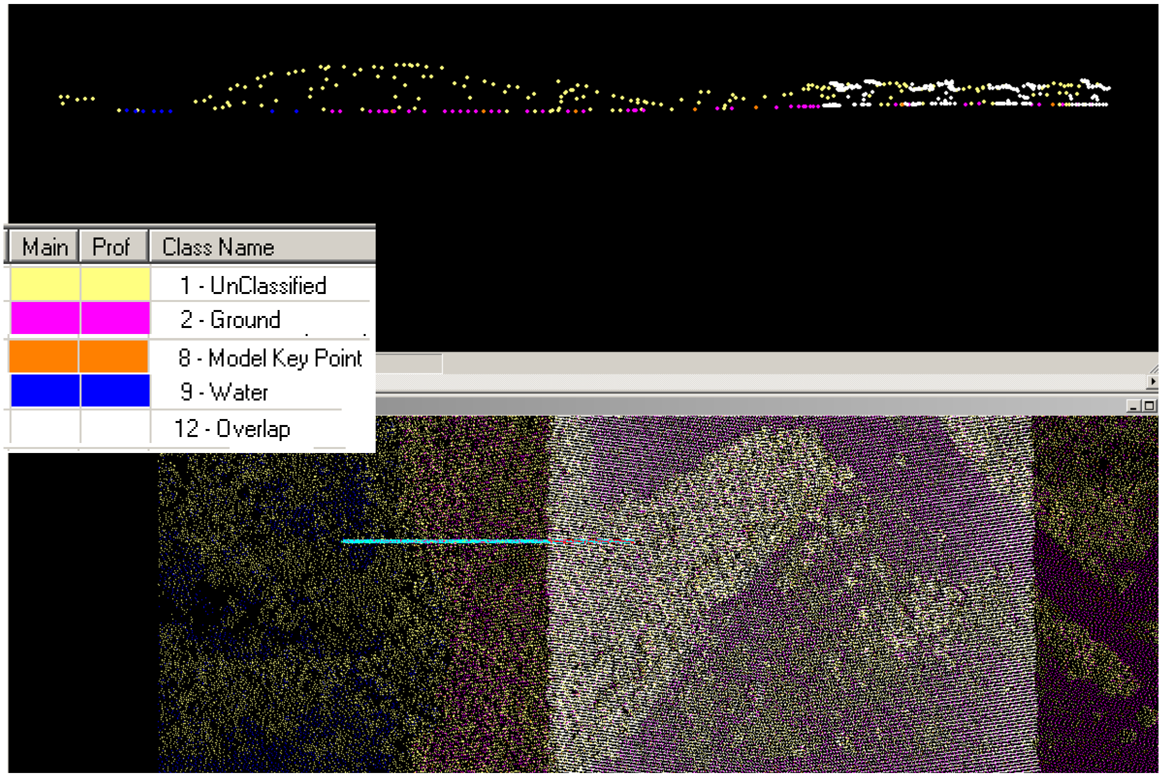

Figure 13 *- Full point cloud colored by classification.*

The second step was to verify data completeness and continuity using the bare-earth DEM with density information, displayed at a macro level. If, during this macro review of the ground models, potential artifacts or large voids are found, the digital surface model (DSM) based on the full point cloud including vegetation and buildings will be used to pinpoint the extent and the cause of the issue. Moreover, the intensity information stored in the LiDAR data can be visualized over this surface model, helping in interpretation of the terrain. Finally, if the analyst suspects a systematic error relating to data collection, a visualization of the 3D raw masspoints is performed, rather than visualizing as a surface.

Dewberry's micro-level qualitative review is the process of importing, comparing and analyzing these two later types of models (DSM with intensity and raw masspoints), along with cross section extraction, surface measurements, and density evaluation.

5.3.2 Quality report

Dewberry's qualitative review consists of a micro visual inspection of all the tiles. There is no automated toolset more effective than the manual inspection by a GIS analyst to find errors in automated processing of LiDAR data. The analyst will inspect the data for processing anomalies, classification errors, and full point cloud artifacts remaining in the ground surface models.

After closely examining the dataset, the bare earth model was determined to be of excellent quality. Dewberry found very few errors in the data as outlined in the text and images below. The only notable anomaly seen in the Laurens LiDAR data was acquisition drop-off which does not affect the usability of the data.

Acquisition "Drop-Off"

Dewberry refers to the lack of returns on certain type of roads, buildings, runways, and parking lots, as acquisition drop-off. Several possible explanations for this anomaly are low gain setting or low emission power, both resulting in a non detection of a weak reflected signal. A weak reflected signal can occur on certain types of asphalt that absorb the near infrared wavelength, see Figure 14. For the roads and buildings there is no simple fix possible except a re-flight without a guarantee of success. The data user should be aware that this issue has almost no impact on the ground integrity: buildings are removed regardless and roads edges are present allowing a proper definition of the terrain. However due to its prevalence in the data, the user should be conscious of these absences of data. Another example is depicted in Figure 15.

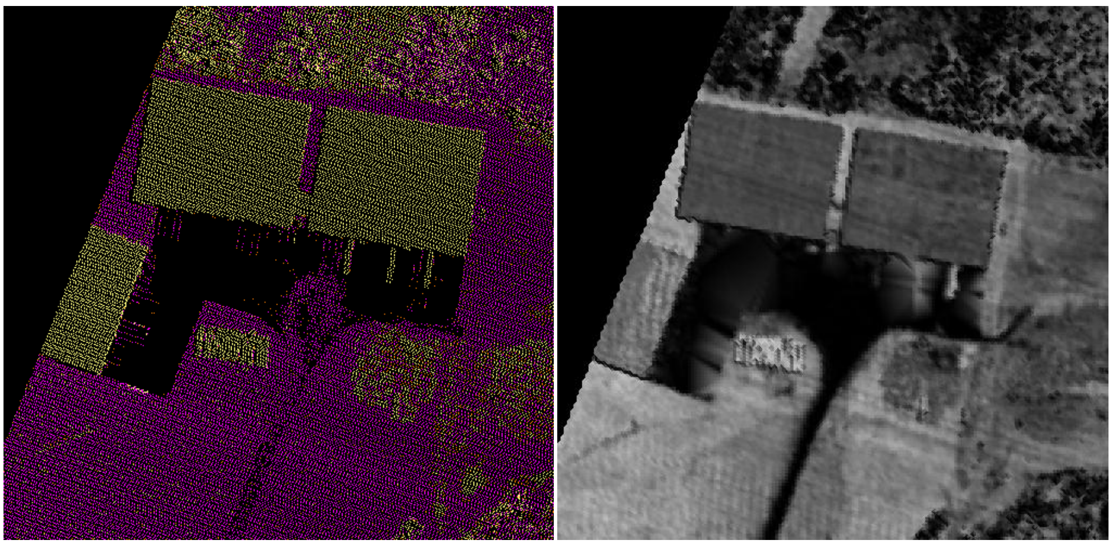

***Figure 14** – 6043-01 Acquisition drop-off in areas where the LiDAR pulse did not return a strong signal. Left image is full point cloud colored by classification; yellow is unclassified (class 1), purple is ground (class 2), black is absence of points. Right image is full point cloud model with intensity.*

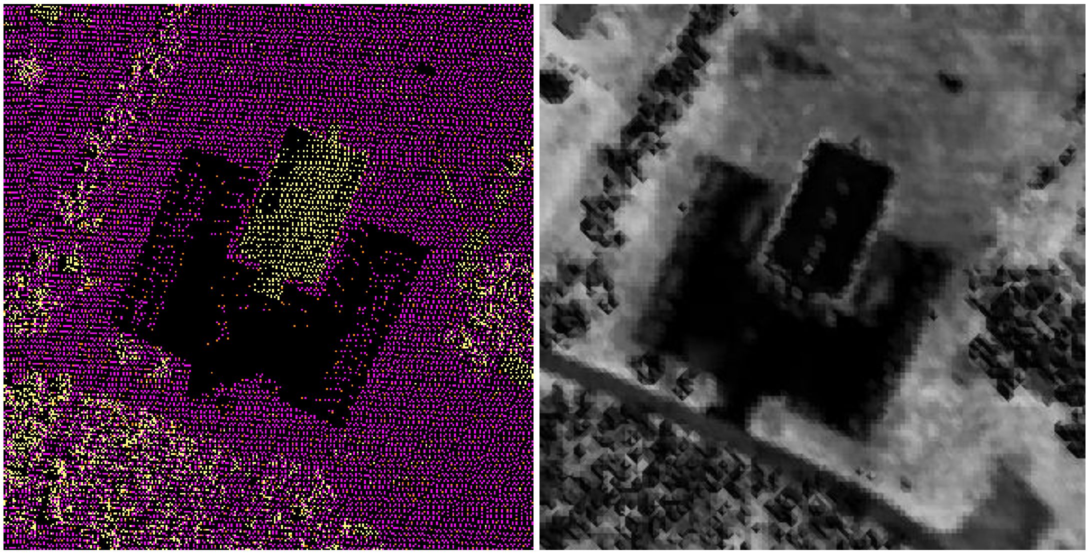

Figure 15 *- 6054-04 Acquisition drop-off. Left image is full point cloud colored by classification; yellow is unclassified (class 1), purple is ground (class 2), black is absence of points. Right image is full point cloud model with intensity.*

Conclusion

Overall the LiDAR data meets the minimum standards for absolute and relative accuracy. The level of cleanliness for the bare-earth terrain easily meets the specifications and no major anomalies were found. The processing performed exceptionally well given the low relief terrain. The figures highlighted above are a sample of the minor issues that were encountered and are not representative of the majority of the data. The intensity images meet specifications and the terrain and multipoint entities are correctly derived from the classified bare earth LiDAR points.

Appendix A Checkpoints

The horizontal coordinate system is South Carolina State Plane **International feet,** horizontal datum NAD83 **HARN** with **elevation in meters** (NAVD88).

The point numbering scheme uses a three digit sequence starting with the county number (SC numbers its counties in alphabetical order), a dash, followed by zone number, a dash and then a sequence number corresponding to order of collection within the zone, the land cover code was concatenated in front of the number.

pointNo	easting	northing	elevation	zLidar	LandCoverType	DeltaZ
b30-1-10	1607424	960385.8	199.236	199.1732	Vegetated	-0.063
b30-1-15	1616276	963347.4	220.939	220.7722	Vegetated	-0.167
b30-1-16	1616219	963372	221.668	221.4907	Vegetated	-0.177
b30-3-7	1678311	1017598	226.201	226.1	Vegetated	-0.101
b30-3-8	1684856	1021338	217.734	217.692	Vegetated	-0.042
b30-4-5	1728756	994582.6	201.347	201.4509	Vegetated	0.104
b30-5-12	1682087	972405.4	215.086	215.0645	Vegetated	-0.022
b30-6-10	1672225	937461.1	186.866	186.8497	Vegetated	-0.016
b30-6-12	1671316	936671.2	184.24	184.2079	Vegetated	-0.032
b30-6-13	1673492	936569.3	186.827	186.7548	Vegetated	-0.072
b30-7-15	1725341	882455.9	167.03	166.9952	Vegetated	-0.035
b30-7-19	1710840	882187.2	173.44	173.4676	Vegetated	0.028
b30-7-20	1713682	872631.5	158.957	158.9577	Vegetated	0.001
b30-7-4	1715443	870226.5	149.658	149.5139	Vegetated	-0.144
b30-7-5	1713733	870807.3	156.701	156.7327	Vegetated	0.032
b30-7-7	1712075	878301.3	167.557	167.5125	Vegetated	-0.044
b30-7-8	1712754	879542	165.485	165.4025	Vegetated	-0.083
b30-9-12	1790365	973437.4	127.277	127.3765	Vegetated	0.099
b30-9-4	1781747	985138.8	167.892	167.9715	Vegetated	0.079
b30-9-6	1783391	984365.8	160.236	160.2756	Vegetated	0.040
h30012	1667649	928894.8	144.727	144.5883	Vegetated	-0.139
h30-1-4	1606408	959504.8	173.84	173.7819	Vegetated	-0.058
h30-1-8	1606586	959808	177.984	177.8847	Vegetated	-0.099
h30-2-2	1643069	1037697	262.21	262.1617	Vegetated	-0.048
h30-2-7	1642618	1037870	258.974	258.8799	Vegetated	-0.094
h30-3-2	1685138	1020929	221.057	220.98	Vegetated	-0.077
h30-3-5	1668394	1013617	231.486	231.3601	Vegetated	-0.126
h30-4-4	1728872	994652.2	198.355	198.347	Vegetated	-0.008
h30-5-11	1684530	971635.5	211.564	211.5252	Vegetated	-0.039
h30-5-19	1697835	973202.5	183.691	183.71	Vegetated	0.019
h30-5-9	1687872	973116.2	194.543	194.4625	Vegetated	-0.081
h30-6-1	1656047	931510.3	161.691	161.6163	Vegetated	-0.075

h30-6-2	1664462	939483	161.141	161.065	Vegetated	-0.076
h30-6-3	1667730	928816.6	147.812	147.655	Vegetated	-0.157
h30-6-6	1663370	931111.8	171.65	171.5075	Vegetated	-0.143
h30-6-7	1663612	929468.1	167.183	167.1043	Vegetated	-0.079
h30-6-9	1673827	938685.8	194.726	194.6033	Vegetated	-0.123
h30-7-1	1715864	866187.9	145.396	145.3303	Vegetated	-0.066
h30-7-18	1709410	878766.7	157.472	157.4212	Vegetated	-0.051
h30-7-2	1716239	867052.2	153.251	153.1567	Vegetated	-0.094
h30-8-10	1750664	937545.6	163.529	163.6212	Vegetated	0.092
h30-8-13	1750252	937194.6	167.069	167.1662	Vegetated	0.097
h30-8-18	1759129	932320.6	177.299	177.49	Vegetated	0.191
h30-8-5a	1759392	932306	178.252	178.4349	Vegetated	0.183
h30-8-6a	1759353	932210.3	177.875	177.8589	Vegetated	-0.016
o30014	1659854	938353.8	185.919	185.79	Open Terrain	-0.129
o30-1-1	1606332	959603.7	171.803	171.6585	Open Terrain	-0.144
o30-1-11TT29P	1613452	972192.9	228.299	227.9801	Open Terrain	-0.319
o30-1-14	1613292	972107.5	227.838	227.7824	Open Terrain	-0.056
o30-1-2	1606285	959492.1	170.811	170.5865	Open Terrain	-0.225
o30-2-4	1642996	1037693	261.33	261.192	Open Terrain	-0.138
o30-2-6	1642975	1038006	261.095	260.9567	Open Terrain	-0.138
o30-3-11	1671729	1026759	234.459	234.3669	Open Terrain	-0.092
o30-3-1a	1685201	1020871	221.874	221.7762	Open Terrain	-0.098
o30-3-4KNIGHT	1668345	1013666	230.117	229.9726	Open Terrain	-0.144
o30-3-6RHODES2	1676669	1016269	233.097	232.9942	Open Terrain	-0.103
o30-4-1H87	1729413	994959.8	199.766	199.644	Open Terrain	-0.122
o30-4-3	1729258	994917.8	198.9	198.8061	Open Terrain	-0.094
o30-4-6	1722448	1001178	183.26	183.215	Open Terrain	-0.045
o30-5-1	1689742	967644.3	204.421	204.2605	Open Terrain	-0.160
o30-5-13TT13SJ	1694345	971596.3	187.355	187.2526	Open Terrain	-0.102
o30-5-17	1696036	971429.8	168.53	168.4198	Open Terrain	-0.110
o30-5-18CEDAR	1697797	973413.4	185.017	184.7821	Open Terrain	-0.235
o30-5-2	1689802	967653.1	204.306	204.21	Open Terrain	-0.096
o30-5-3LRN1705	1686469	968727.5	194.558	194.3627	Open Terrain	-0.195
o30-5-6YMCA	1688397	973285.9	182.474	182.3604	Open Terrain	-0.114
o30-5-8	1687798	973342.9	193.453	193.2845	Open Terrain	-0.168
o30-6-11	1668019	929526.1	137.685	137.4979	Open Terrain	-0.187
o30-6-5	1663594	930288	166.344	166.2399	Open Terrain	-0.104
o30-6-8	1668556	941064.6	161.78	161.6524	Open Terrain	-0.128
o30-7-11	1708645	895445.7	179.679	179.6567	Open Terrain	-0.022
o30-7-13	1722304	878038.5	180.834	180.7427	Open Terrain	-0.091
o30-7-16	1716902	885590.2	180.579	180.4928	Open Terrain	-0.086
o30-7-17	1714589	885116.2	185.185	185.1186	Open Terrain	-0.066

o30-7-3	1714755	866147.1	138.081	138.0041	Open Terrain	-0.077
o30-7-6	1713232	873101.6	164.151	164.1001	Open Terrain	-0.051
o30-8-1	1759526	932299	177.14	177.1525	Open Terrain	0.013
o30-8-15	1760938	942380.1	165.697	165.7991	Open Terrain	0.102
o30-8-2	1759536	932330.2	176.795	176.8269	Open Terrain	0.032
o30-8-3	1750561	937485.2	164.953	164.9945	Open Terrain	0.041
o30-8-4	1759492	932295.9	177.553	177.4815	Open Terrain	-0.071
o30-8-8HOPEWELL	1750502	937365.2	169.221	169.2276	Open Terrain	0.007
o30-9-10SILVERTONE	1790239	973477.2	129.188	129.2631	Open Terrain	0.075
o30-9-1REDBONE	1781920	984574.9	156.757	156.8637	Open Terrain	0.107
o30-9-2	1781917	984588	157.274	157.3159	Open Terrain	0.042
o30-9-8	1783478	984416.5	161.506	161.4821	Open Terrain	-0.024
oNEELB	1718580	883206.2	179.344	179.233	Open Terrain	-0.111
oPINELANDFORESTA	1719280	868353.8	167.636	167.5944	Open Terrain	-0.042
oSALUDARIVER	1606294	959550.5	174.851	174.5783	Open Terrain	-0.273
u30-1-12	1613378	972211.2	228.228	228.1595	Urban	-0.069
u30-1-5	1606387	959567.6	175.238	175.0705	Urban	-0.167
u30-2-16	1648971	1041540	223.523	223.2713	Urban	-0.252
u30-2-3	1643037	1037718	262.11	261.9282	Urban	-0.182
u30-2-5	1643088	1037920	262.33	262.1679	Urban	-0.162
u30-3-10	1671680	1026686	235.634	235.5419	Urban	-0.092
u30-3-3	1684920	1021015	221.078	220.9553	Urban	-0.123
u30-4-2	1729409	994902.7	199.828	199.7396	Urban	-0.088
u30-4-8	1731548	1005355	139.38	139.285	Urban	-0.095
u30-5-14	1694371	971380.8	186.99	186.9586	Urban	-0.031
u30-5-15	1694392	971568.5	187.502	187.4949	Urban	-0.007
u30-5-16	1696251	971559.4	168.412	168.3475	Urban	-0.065
u30-5-4	1686356	969119.4	196.348	196.1587	Urban	-0.189
u30-5-7	1687910	973376.4	191.227	191.0694	Urban	-0.158
u30-7-10	1708556	895489.3	178.676	178.6087	Urban	-0.067
u30-7-9	1709785	890499.3	175.279	175.2073	Urban	-0.072
u30-8-11	1750542	937544.8	165.285	165.295	Urban	0.010
u30-8-16	1760924	942453.8	165.798	165.8995	Urban	0.101
u30-8-7a	1759368	932258.6	178.184	178.2071	Urban	0.023
u30-8-9	1750561	937485.1	164.994	164.9943	Urban	0.000
u30-9-11	1790237	973513.9	129.083	129.2152	Urban	0.132
w30-1-3	1606323	959485.4	171.725	171.675	Vegetated	-0.050
w30-1-9	1606529	959787.2	176.634	176.5974	Vegetated	-0.037
w30-2-130001	1643054	1037590	262.258	262.1834	Vegetated	-0.075
w30-2-14	1648965	1041577	223.646	223.4537	Vegetated	-0.192
w30-2-15	1648951	1041615	223.525	223.3676	Vegetated	-0.157
w30-2-8	1642592	1037861	258.864	258.6863	Vegetated	-0.178

w30-3-9	1684903	1021379	216.057	216.0846	Vegetated	0.028
w30-4-7	1731659	1005334	139.76	139.7526	Vegetated	-0.007
w30-5-10	1687857	973054.3	194.215	194.115	Vegetated	-0.100
w30-5-20	1698769	968763.1	173.36	173.2849	Vegetated	-0.075
w30-5-5	1687424	969453.7	205.574	205.402	Vegetated	-0.172
w30-6-4	1667689	928776	148.566	148.481	Vegetated	-0.085
w30-7-14	1724406	876852	177.721	177.658	Vegetated	-0.063
w30-8-12	1750576	937617.6	164.546	164.7898	Vegetated	0.244
w30-8-14Y89	1760971	942470	167.054	167.0616	Vegetated	0.008
w30-8-17	1759178	932268.9	177.409	177.5688	Vegetated	0.160
w30-9-13	1790140	973586.1	131.195	131.3137	Vegetated	0.119
w30-9-3	1781865	984635.2	157.647	157.7263	Vegetated	0.079
w30-9-5	1781643	985286.7	163.612	163.6844	Vegetated	0.072
w30-9-7	1783476	984351.6	160.985	160.9436	Vegetated	-0.041